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Microstructural analysis of fractured orthopedic implants

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Despite the undeniable advantages of medical implants, their fractures remain a problem. The main factors considered as potential causes of fracture were assigned to the patient's condition, geometry of the implant and its mechanical loads. Nevertheless, the microstructural mechanisms of fracture occurrence have not been investigated in detail as yet. Thus, fracture mechanisms and their causes were studied in the case of selected types of four implants with different geometries (pure titanium locking plate, pure titanium femoral implant, Ti-6Al-4V titanium alloy pelvic implant, X2CrNiMo18 14-3 steel femoral implant). Each implant fractured in the human body. The scanning electron microscopy (SEM) was used to qualitatively examine and determine the potential cause of implants fracture.

It was found that the implants destructions mainly occurred in consequence of mechanical overloads resulting from repetitive, banned excessive limb loads or singular, un-intendent, secondary injures. The design of implants leads to the generation of stress concentrators that serve as initiators of cracks. The microscopic analysis of the fractured surfaces of the implants revealed that, regardless of the initial material state and geometry, the fracture was caused by the concentration of the stress forces in its holes, including the threaded parts, where the crack initiated and propagated within the material (Figure 1). Most probably, the implants were subjected to an excessive fatigue load with additional effects caused by the interaction between the screws and threaded holes. The very tight connection between the screws and threated holes of the implant initiated cracks that led to significant wear between the working surfaces. The wear of threads of screws and plates might reduce the rigidity of the connection between the bone and the implant, thus enhancing the temporary loads between them that promoted the propagation of the implant's cracks.

The results of this work enable to conclude that the construction of orthopedic implants is not fully sufficient to transduce mechanical loads acting over them due to an increasing mass of treated patients and much higher their physical activity. One can require to increase the thickness of implant dimensions, especially in the areas with holes in order to reduce the risk of implant fracture.

Keywords: medical fixation devices; orthopedic prostheses and implants; titanium; titanium alloy; stainless steel; microscopic fracture analysis

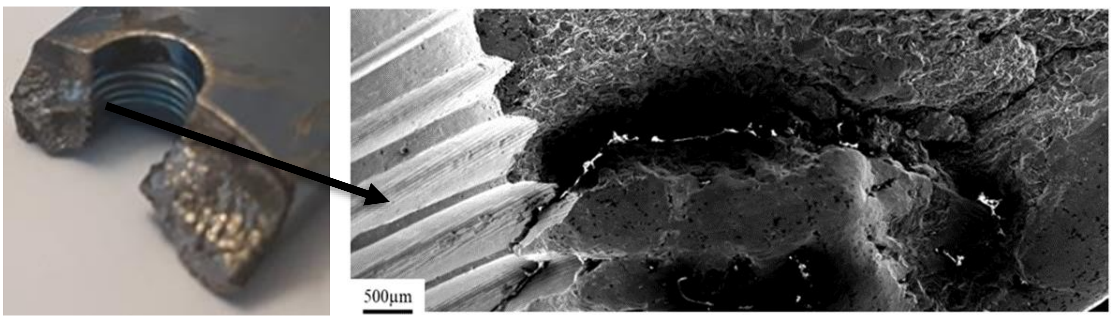

Figure 1. General view of the exploited titanium implant with localized crack propagation initiated in the central part of the thread captured by SEM.